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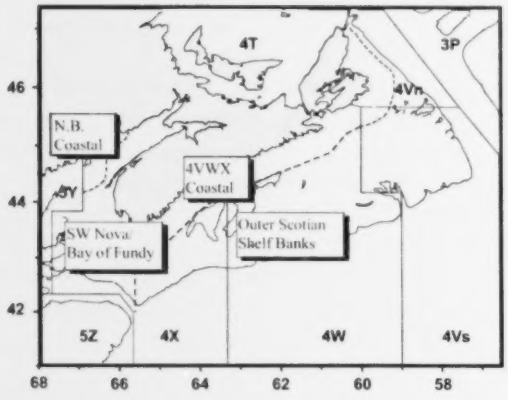
Maritimes Region
Canadian Science Advisory Secretariat
Science Advisory Report 2006/031

2006 ASSESSMENT OF 4VWX HERRING



Context

In support of scientific advice for the 2005/06 fishery, the 2006 assessment of the 4VWX herring stock complex was undertaken over two meetings of the Regional Advisory Process. An initial meeting was held in Yarmouth, N.S., 22 March 2006 to review the data inputs. A second meeting was held in Dartmouth, N.S., 11-12 April 2006 to review and evaluate biological and fishery information on 4VWX herring status as a basis for establishing quota for the 2005/2006 fisheries, as required in the Integrated Fisheries Management Plan. The terms of reference included an evaluation of the SW Nova Scotia / Bay of Fundy spawning component, and compilation and review of information regarding the offshore Scotian Shelf and the coastal Nova Scotia spawning components. Participants included scientists, fishery managers, and representatives of the industry, provincial governments and other stakeholders.

The 2003-2006 Scotia-Fundy Herring Integrated Fisheries Management Plan (DFO 2003) set out principles, conditions, and management measures for the 4VWX herring fisheries. The main principle stated in the plan is "the conservation of the herring resource and the preservation of all of its spawning components".

Three conservation objectives developed and reviewed in 1997 appear in the plan:

1) *To maintain the reproductive capacity of herring in each management unit through:*
   - *persistence of all spawning components in the management unit;*
   - *maintenance of biomass of each spawning component above a minimum threshold;*
   - *maintenance of a broad age composition for each spawning component; and*
   - *maintenance of a long spawning period for each spawning component.*
2) *To prevent growth overfishing:*
   - *continue to strive for fishing mortality at or below $F_{0.1}$*
3) *To maintain ecosystem integrity/ ecological relationships ("ecosystem balance"):*
   - *maintain spatial and temporal diversity of spawning*
   - *maintain herring biomass at moderate to high levels*

Progress against these objectives was evaluated at this meeting.

Since 1995, the herring stock assessment and related research has been increasingly dependant on a number of projects undertaken with the assistance of the fishing industry. These include industry sampling of biological characteristics of the catch, as well as acoustic surveys using industry vessels and tagging. A major review of the assessment framework including aspects of stock structure, tagging results, acoustic surveys and design, assessment formulations and alternative models/approaches is planned for the fall and winter of 2006-07.

SUMMARY

SW Nova Scotia / Bay of Fundy

- None of the conservation objectives specified for this fishery are being met.
- Age distribution in the catch remained contracted, with a further decline in the proportion of ages 5+ in the fishery.
- The acoustic survey index from the spawning grounds in 2005 indicates a decline in spawning stock biomass (SSB) from 2004.
- A population model (calibrated with the German Bank acoustic index) indicates that fishing mortality (F) has been very high in recent years and that the current SSB is less than 100,000t.
- Catches of less than about 16,000t would be required to have a low to neutral probability of exceeding $F_{0.1}$.
- Catches as high as 35,000t should result in a neutral (50%) probability of a moderate (20%) biomass increase.
- At status quo (catches of 50,000t) there is a 40% probability that biomass will not increase at all, and a high probability (90%) that it will not increase by a moderate (20%) amount.
- The benefits of the reduced quota in 2005 have not been in place for a sufficient time to be reflected in the biological characteristics of the population. Industry stated that they took action to avoid young fish in 2005 and the fraction of younger fish removed was substantially reduced.

Offshore Scotian Shelf Banks

- Since 1996, a fishery has taken place on feeding aggregations on the offshore banks, primarily in May and June, with catches ranging from 1,000 to 20,000t. Total landings in 2005 were 5,200t.
- The summer bottom trawl research survey again demonstrated considerable abundance of herring, widely spread, over the offshore banks of the Scotian Shelf.
- There is little new information to add and no reason to change the previous recommendation that the initial catch allocation for 2006 should not exceed the 12,000t used in the fishing plan.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

- In 2005, there was an increase in surveyed acoustic biomass in both the Little Hope and Halifax areas after a decline in 2004. A survey with an acoustic recorder was completed for the first time in the Glace Bay area.
- Management approaches and recent research efforts have improved knowledge in three areas (Little Hope/Port Mouton, Halifax/Eastern Shore and Glace Bay), but there has been no increase in knowledge in adjacent areas.
- There should be no large increases in effort in coastal spawning areas and no new fisheries developed when there is uncertainty regarding stock composition and degree of mixing.

SW New Brunswick Migrant Juvenile

- Landings were substantially lower than in 2004 and there has been a trend of decreasing number of weirs in this fishery and decreasing landings over the past decade.

BACKGROUND

Species Biology

Atlantic herring is a pelagic species found on both sides of the North Atlantic. Herring spawn in discrete locations, to which they are presumed to home. Herring first mature and spawn at three or four years of age (23 to 28 cm or 9 to 11 in), then begin an annual pattern of spawning, over-wintering, and summer feeding, which often involves considerable migration and mixing with members of other spawning groups. Most fishing takes place on dense summer feeding, over-wintering, and spawning aggregations.

The 4VWX management unit contains a number of spawning areas, separated to various degrees in space and time. Spawning areas in close proximity with similar spawning times, and which share a larval distribution area, are considered part of the same complex. These undoubtedly have much closer affinity than spawning areas that are widely separated in space or time, and do not share a common larval distribution. Some spawning areas are large and offshore, whereas others are small and more localized, sometimes very near shore or in small embayments. The situation is complicated further as herring migrate long distances and mix outside of the spawning period both with members considered part of the same complex and with members of other spawning groups. For the purposes of evaluation and management, the 4VWX herring fisheries are divided into four components:

1. SW Nova Scotia / Bay of Fundy spawning component
2. Offshore Scotian Shelf banks spawning component
3. Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia spawning component
4. SW New Brunswick migrant juveniles

Each component has several spawning areas, and there is mixing of fish among spawning components outside of the spawning period. Industry and management have explored means of managing the complexity within each component (such as distributing fishing effort among spawning areas according to their relative size) and of taking appropriate account of interaction among components (such as fishing restrictions on some areas of mixing). Fisheries in the 4VWX area in recent years have been dominated by purse seine, weir and gillnet, with relatively minor landings by shutoff and trap.

ASSESSMENT FOR THE SOUTHWEST NOVA SCOTIA / BAY OF FUNDY SPAWNING COMPONENT

Fishery

Landings in 2004/05 were 48,900t against a TAC of 50,000t (Figure 1) for the SW Nova Scotia / Bay of Fundy component. The entire TAC was not caught due to the lag time with the transfer of quota from fixed gear allocations that occurred late in the season. There were additional landings of 25,000t in the non-stock components for an area total of 74,000t.

Table 1. Reported landings and TAC for the 4VWX herring fishery by major stock component from 2000 to 2005 with averages for prior decades.

Landings (thousands of tonnes)

Year	Average 1980-89	Average 1990-99	2000	2001	2002	2003	2004	2005
4WX SW NS TAC*	106	112	100	78	78	93	83	50
4WX SW NS*	131	96	85	72	77	89	78	49
4VWX Coastal NS^	<1	4	4	6	10	9	7	7
Scotian S. Banks^	<0.1	13	2	12	7	1	4	5
SW NB^	24	24	17	20	12	9	21	13
Total Landings	155	137	108	110	106	108	110	74

* Quota year from Oct. 15 of the preceeding year to Oct 14 of the current year

^ Calendar year from Jan. 1 to Dec. 31

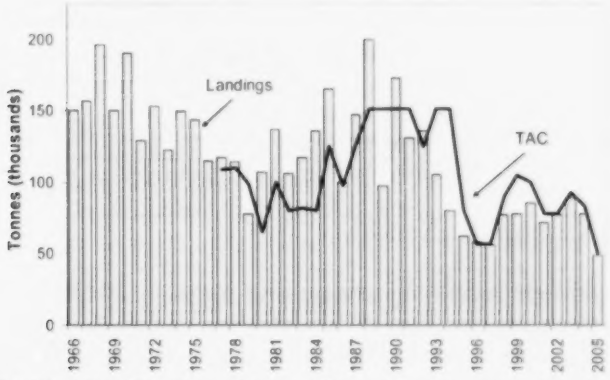


Figure 1. Landings and TAC for the SW Nova Scotia / Bay of Fundy spawning component.

The 2001 year-class (at age 4) represented about 40% of the numbers and 52% of the weight of herring landed in the SW Nova Scotia / Bay of Fundy component (Figure 2). The 2002 year-class (at age 3) represented 37% of the numbers and 29% of the weight in the landings. Age 4 fish were predominant by weight across all gear components except the fall purse seine fishery (Oct. 15 to Dec. 31, 2004) which landed mostly age 2 fish.

Prior to 2005, there was targeting of young fish and the high proportion of juveniles in the catch resulted in reduced yield. As a result of the concern that 2 year olds were being targeted, industry attempted to re-direct to older fish. In 2005, 2 year olds represented only 16% of the catch, a reduction from 32%. The total removals of fish by numbers were also reduced by close to 50%.

Age distribution in the catch remained contracted, with a further decline in the proportion of ages 5+ in the fishery (Figure 3). There was a decline in the percentage of age 2's and an increase in the percentage of age 4's in the catch in 2005 (Figure 3, 4).

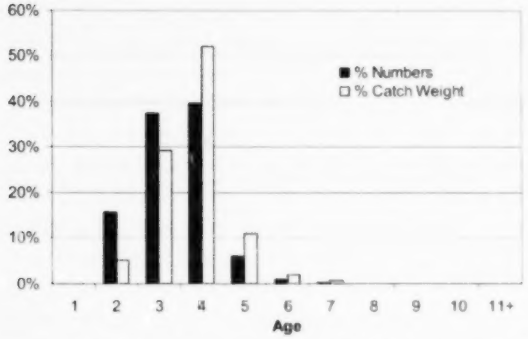


Figure 2. Catch at age for the 2005 overall SW Nova Scotia / Bay of Fundy herring spawning component.

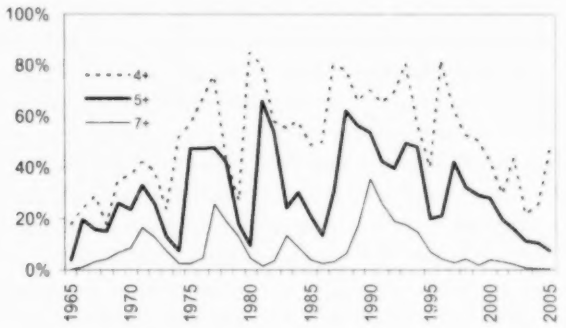


Figure 3. Overall proportions of 4+, 5+ and 7+ herring in the catch at age from the SW Nova Scotia / Bay of Fundy spawning component.

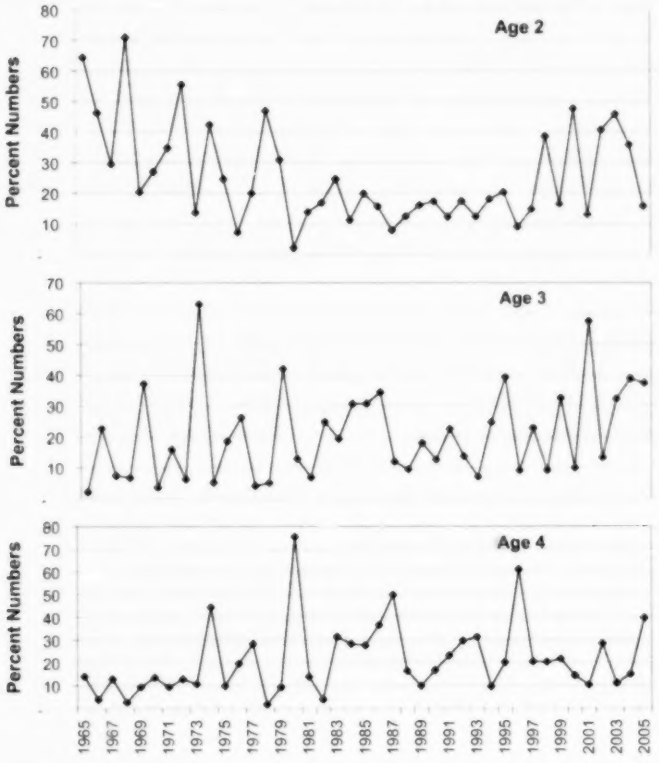


Figure 4. Percent numbers from the catch at age from 1965-2005 for ages 2, 3 and 4 for the SW Nova Scotia / Bay of Fundy herring spawning component.

Acoustic Surveys

Automated acoustic recording systems deployed on commercial fishing vessels were used to document the distribution and abundance of herring in structured industry vessel surveys. Scheduled surveys were conducted every 2 to 3 weeks on the main spawning components and

an index of spawning stock biomass for each component was estimated by summing these results.

In 2005, three surveys were conducted in Scots Bay and three on German Bank, a reduction of one survey from each location in the previous years. Individual survey area coverage was good and consistent with established protocols. Additional acoustic data from fishing nights in Scots Bay and German Bank were examined. At the data input meeting, industry expressed concern about the overall Scots Bay biomass index estimate due to the lateness of the initial survey, time intervals between surveys, the presence of spent fish in catches just prior to the first acoustic survey, and the possibility that some fish may have also come onto the grounds and left between surveys. The spawning fishery period in Scots Bay was reduced from 2004. The duration of the spawning fishery on German Bank was similar to the previous year but began later in August since 2003. No structured surveys occurred on German Bank after October 4.

The documented amount of spawning fish on Trinity Ledge was lower than in the past three years but survey coverage was limited. There were no surveys and no reports of spawning herring on Lurcher Shoal or Seal Island spawning grounds.

Table 2. Acoustic survey biomass index for SW Nova Scotia / Bay of Fundy spawning component for 1999 to 2005 ('000's t). Blanks indicate that no survey was undertaken.

Acoustic Survey SSB (000's t)							
Location	1999	2000	2001	2002	2003	2004	2005
Scots Bay	41	106	164	141	134	108	17
Trinity Ledge	4	1	15	8	15	7	5
German Bank	461	356	191	393	344	368	211
Spec.* (spring)			1		1		0.3
Subtotal	506	463	370	542	493	482	233
Spec.* (fall)			88				
Seal Island			3	1	12		
Browns Bank			46				
Overall SSB	506	463	507	543	506	482	233
Standard Error (SE)	19%	14%	10%	9%	17%	15%	28%

* Spec. - Spectacle Buoy

The biomass index estimated from acoustic surveys was approximately 233,000t and represents a substantial decline in all areas from recent years (Figure 5).

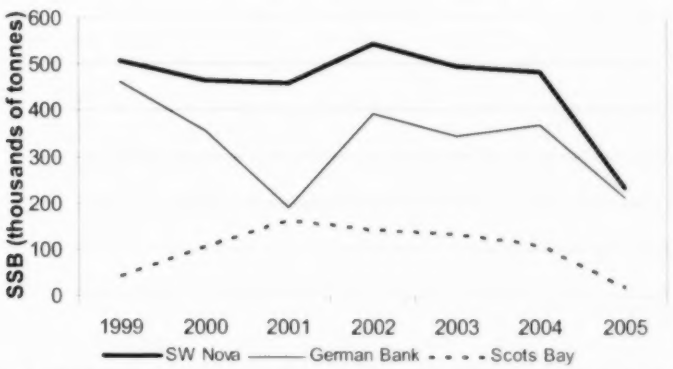


Figure 5. SSB index from acoustic surveys for the SW Nova Scotia / Bay of Fundy spawning component (note that the 'SW Nova' values are from the 'Subtotal' row in Table 2).

Between 1999 to 2003 acoustic survey results were used as minimum estimates of absolute SSB abundance and the population was considered to be approximately 500,000t. An SSB of that size since the late 1990s would have been expected to result in substantial growth of the population, improved age composition and low fishing mortality, given reasonable recruitment and the landings over that period. The expected growth in the population was not observed in the surveys and increase in proportion of older fish was not observed in either the surveys or the fisheries, and it was noted that the declining proportion of older fish in the population suggested that the total mortality on this stock is high.

Stock Trends and Current Status

A population model (Virtual Population Analysis, VPA) was conducted on this stock component. The previous assessment (2005) concluded that the SSB from acoustic surveys summed together results in an overestimate but that as an index of abundance, acoustic surveys follow the biomass trend from the population model. While the discrepancy between the acoustic estimate of absolute SSB abundance and the VPA has not been resolved, there are several potential explanations. A tagging study undertaken in 2005 on both German Bank and Scots Bay confirmed that residence time of a portion of the fish on the spawning grounds may exceed the assumed two week turnover interval. However, adjustments to the acoustic biomass estimates, based on preliminary analysis of the tagging data from Scots Bay, appear to only account for about 40% of the difference between VPA and acoustic estimates. Biomass estimates from single acoustic surveys exceeded total VPA results for the series. The difference is not fully explained by possible double counting by the acoustic surveys, but could also relate to other issues including an inappropriate target strength coefficient for converting backscatter to biomass or unaccounted mortality.

The acoustic survey index from the spawning grounds in 2005 indicates a decline in spawning stock biomass from 2004 (Figure 5). A VPA was calibrated with the trends in acoustic survey results, using fishery catch statistics and sampling for size and age composition of the catch for 1965-2005. Various VPA formulations were investigated and two models were presented for review. One model used the overall acoustic survey index (Scots Bay, Trinity Ledge, Spectacle Buoy, German Bank) for ages 4 to 8 and the second model used only the German Bank acoustic survey index for the same age range.

A population model calibrated with the German Bank acoustic index only was selected to overcome uncertainty with survey timing in Scots Bay. The VPA indicates that fishing mortality (F) has been very high in recent years and that the current SSB is less than 100,000t (Figures 6 and 7). The reduced quota in 2005 resulted in a lowering of F but it is still high relative to $F_{0.1}$(0.23).The benefits of the reduced quota are reflected in the reduced fishing mortality rate in 2005 but the adjustments have not been in place for a sufficient period to be reflected in the biological characteristics of the population.

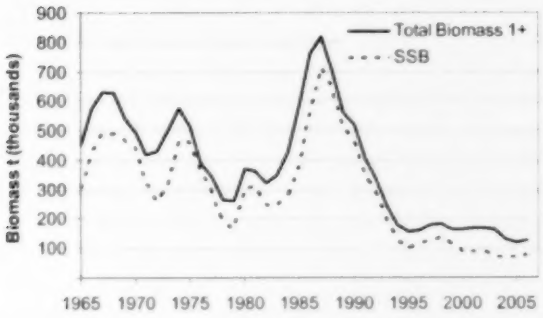


Figure 6. Total biomass and SSB from a VPA calibrated with the German Bank acoustic index.

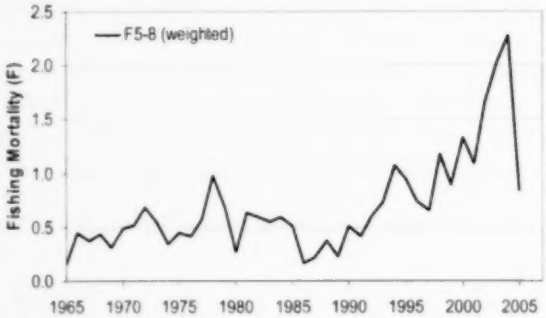


Figure 7. Fishing mortality (ages 5-8 weighted by population numbers) from a VPA calibrated with the German Bank acoustic index.

Sources of Uncertainty

- There is no independent index of recruitment and a large fraction of the catch is dependent on recruiting year classes.
- Industry observed that herring remained close to bottom in 2005, which may have had an impact on the estimation of biomass from acoustic surveys.
- There has been variation in the number of surveys conducted on German Bank and in Scots Bay over the time series. Scots Bay surveys in 2005 did not cover the entire spawning season.
- There is uncertainty related to residency time on the spawning grounds. Tagging conducted in Scots Bay and on German Bank indicated that some tagged fish remain on the spawning grounds for a longer period than the interval between surveys. The tagging information was not used to adjust the acoustic estimates for this assessment. Residency time and its impact on the acoustic estimates will be reviewed in the framework assessment.
- The absolute abundance calculated from the acoustic surveys was consistently higher than the VPA estimates of biomass. This occurred for some years based on individual surveys.
- Acoustic target strength conversion to biomass is a point of uncertainty and more work is required on the estimation.
- The integration factor is a source of uncertainty, since the methodology of the acoustic calibration was changed in 2003. In order for the full time series to be consistent with the integration factor the data prior to 2003 must be re-analyzed.
- There was uncertainty associated with the level of noise in the acoustic data collected on some of the acoustic transects related to individual vessels.

CONCLUSIONS AND ADVICE

The objectives for this stock from the management plan and the current observations are summarized below. None of the conservation objectives specified for this fishery are being met.

Objective	2005 observations
Persistence of all spawning components	Trinity Ledge remains at a low level; no reports of spawning in Seal Island or Lurcher Shoal areas
Maintain biomass of each spawning component	German Bank and Scots Bay have declining biomass estimates. Trinity Ledge, Lurcher Shoal and Seal Island are at low biomass. Substantial decline in the acoustic index from 2004.
Maintain broad age composition	Further decline in proportion of older ages. Age composition is very narrow. Targeting of small fish was reduced in 2005.
Maintain long spawning period	Delayed start and shorter duration of spawning in 2005 for both Scots Bay and German Bank.
Fishing mortality at or below $F_{0.1}$	Fishing mortality is high and well above $F_{0.1}$.
Maintain spatial and temporal diversity of spawning	Insufficient spawning in some areas.
Maintain biomass at moderate to high levels	SSB is at lowest recorded level.

This assessment has confirmed a continued deterioration in the state of the resource, as noted in previous assessments. A harvest strategy that allows rapid population rebuilding is strongly recommended. Projection results and risk analysis are provided in terms of the consequences of various catch quotas (yield) (Figure 8). Catches of less than about 16,000t would be required to have a low to neutral probability of exceeding $F_{0.1}$. Catches as high as 35,000t should result in a neutral (50%) probability of a moderate (20%) biomass increase. At status quo (catches of 50,000t) there is a 40% probability that biomass will not increase at all and a high probability (90%) that it will not increase by a moderate (20%) amount.

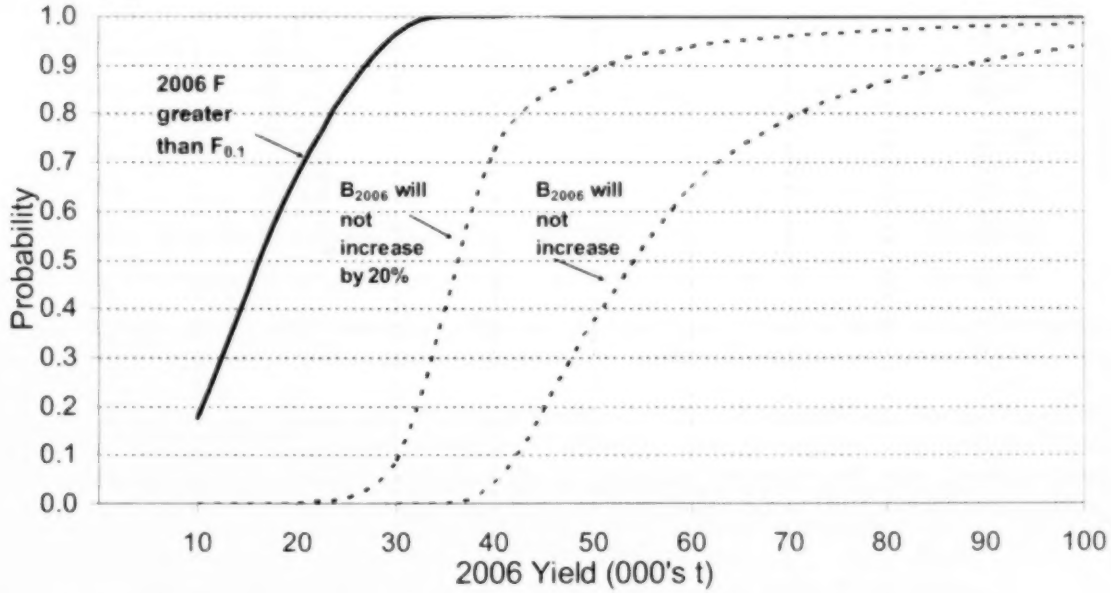


Figure 8. Projection probabilities for the SW Nova Scotia / Bay of Fundy spawning component.

OTHER CONSIDERATIONS

The benefits of the reduced quota in 2005 have not been in place for a sufficient time to be reflected in the biological characteristics of the population. Industry stated that they took action to avoid young fish in 2005 and the fraction of younger fish removed was substantially reduced.

About half of the catch biomass in recent years has been comprised of ages 2 and 3, and the abundance of these recruiting ages is uncertain. The acoustic index provides independent information on the spawning stock biomass but does not provide data on younger age classes. The size of herring year-classes is highly variable. There is no index of recruitment and thus the initial estimate of year-class size can only be derived from the VPA. Younger ages are derived from the VPA and are based primarily on estimates.

ASSESSMENT, CONCLUSIONS AND ADVICE FOR OTHER COMPONENTS

Offshore Scotian Shelf

Since 1996, a fishery has taken place on feeding aggregations on the offshore banks, primarily in May and June, with catches ranging from 1,000 to 20,000t (Figure 9). Total landings in 2005 were 5,200t with most landings by purse seine in May and June, in the vicinity of the Patch, Emerald and Western Bank. There was also effort in the late fall by midwater trawlers with 885t caught in the offshore east of the Patch.

The 2000 to 2001 year-classes (ages 5 and 4) made up most of the age composition of the Scotian Shelf fishery, with age 5 dominating in both number and weight (Figure 10).

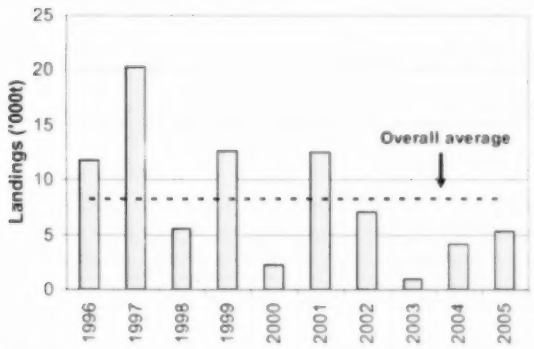


Figure 9. Offshore Scotian Shelf herring landings since 1996 with overall average for the period.

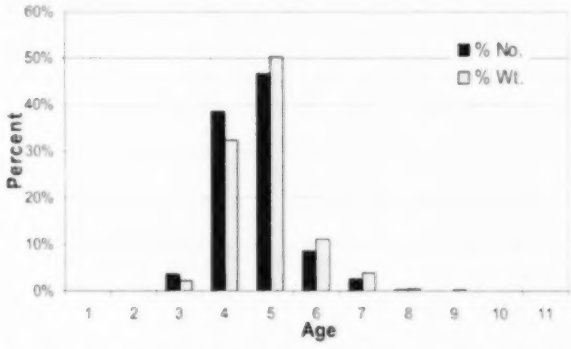


Figure 10. Catch at age by purse seine for the 2005 Offshore Banks herring component.

There have been no industry surveys of the offshore Scotian Shelf area since 2001. The summer bottom trawl research survey again demonstrated considerable abundance of herring, widely spread, over the offshore banks of the Scotian Shelf (Figure 11). Information from previous assessments indicated the presence of at least some autumn spawning on Western Bank in recent years.

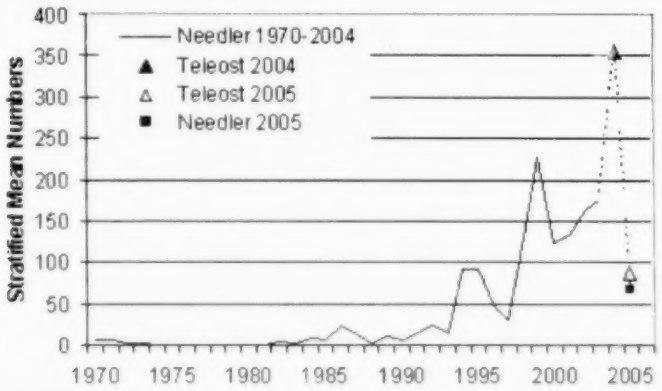


Figure 11. Number of herring caught per standard tow in the DFO summer bottom trawl survey of the offshore Scotian Shelf Banks, 1970 to 2005 (strata 55-78; from Sable Island to Baccaro Line). Survey results for Teleost and Alfred Needler in 2004-2005 are identified individually.

There is little new information to add and no reason to change the previous recommendation that the initial catch allocation for 2006 should not exceed the 12,000t used in the fishing plan. The industry should be encouraged to explore and undertake surveys of the offshore area.

Coastal (South Shore, Eastern Shore and Cape Breton) Nova Scotia

There is no quota for the coastal Nova Scotia spawning component and, apart from four areas, the size and historical performance of various spawning groups are poorly documented. In addition to the traditional bait and personal-use fisheries, directed roe fisheries have occurred on several spawning grounds in recent years.

Table 3. Recorded landings (t) of herring from major gillnet fisheries on the Coastal Nova Scotia spawning component.

Landings (000's t)

	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Little Hope	0.0	0.5	1.2	2.9	2.0	2.9	4.0	4.5	1.3	2.2
Eastern Shore	1.3	1.5	1.1	1.6	1.4	1.9	3.3	2.7	4.2	3.5
Glace Bay	0.0	0.2	1.7	1.0	0.8	1.2	3.1	1.9	1.5	0.6
Bras d'Or	0.2	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total	1.5	2.3	4.1	5.6	4.3	6.0	10.4	9.1	7.0	6.3

As the inshore roe fisheries off Glace Bay, East of Halifax and Little Hope have developed, participants have contributed to sampling and surveying of the fisheries.

Table 4. Estimated spawning biomass of herring from major gillnet fisheries in the Coastal Nova Scotia spawning component. Blanks represent no survey completed.

Acoustic Survey SSB (000's t)

	1998	1999	2000	2001	2002	2003	2004	2005
Little Hope	14.1	15.8	5.2	21.3	56.0	62.5	15.6	39.5
Eastern Shore	8.3	20.2	10.9	16.7	41.5	76.5	18.2	28.1
Glace Bay		2.0		21.2	7.7	31.5	0.0	2.2
Bras d'Or		0.5	0.1					

In 2005, there was an increase in surveyed acoustic biomass in both the Little Hope and Halifax areas after a decline in 2004. A survey with an acoustic recorder was completed for the first time in the Glace Bay area (previous estimates were based on mapping surveys). As indicated for the SW Nova Scotia / Bay of Fundy component, summing of multiple surveys may result in overestimates of SSB due to double counting. However, the majority of surveys of the Coastal Nova Scotia spawning component was undertaken on spatially separated aggregations of fish.

Management approaches and recent research efforts have improved knowledge in three areas (Little Hope/Port Mouton, Halifax/Eastern Shore and Glace Bay), but there has been no increase in knowledge in adjacent areas. Individual spawning groups within this component are considered vulnerable to fishing because of their relatively small size and proximity to shore. As in the past five years, it is recommended that no coastal spawning areas experience a large effort increase until enough information is available to evaluate the state of that spawning group. There should be no large increases in effort in coastal spawning areas and no new fisheries developed when there is uncertainty regarding stock composition and degree of mixing.

It has been noted since 1997 that the status of herring in the Bras d'Or Lakes is cause for concern. It is therefore appropriate to reiterate that no fishing should take place on this spawning component.

SW New Brunswick Migrant Juveniles

Approximately 13,050t of herring, considered to be a mixture of fish originating primarily from NAFO Subarea 5, were landed in the traditional New Brunswick weir and shutoff fishery in 2005. Landings were substantially lower than in 2004 and there has been a trend of decreasing number of weirs in this fishery and decreasing landings over the past decade.

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